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THE SEX CYCLE OF THE GERM PLASM

Its Relation To Sex
Determination

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BY THOMAS E. REED, M.D.

PART I.

PRIMITIVE man has been found to theorize in his fanciful way upon astronomical phenomena long before it occurred to him that there was any need for an explanation of some manifestations of even more intimate connection with himself; these are the expressions he constantly sees in himself and about him of the life force. However, as knowledge increased the external world was separated in the mind of man into two categories: the category of living matter and the category of matter which as far as could be seen had no innate power of reacting to its environment or of reproducing itself. We know that even in the mists of prehistoric times, or with the primitive peoples of any age this sharp distinction between the living and non-living, organic and inorganic matter has almost instinctively been drawn.

We do not wish to be here understood as holding that there is such a real distinction between these two phases of the material world. Some recent discoveries would seem to convey hints that this barrier through which a break has so long been sought, and sought in vain, may be broken down. We are considering now the more apparent distinctions between living and non-living matter. Of these the one which possesses the merit of being the most easily applied as a test, is the power possessed by all living organisms of reproducing themselves.

There are several ways by which this flow of reproduction is sustained as an unbroken and eternal stream. These we may refer to later, but at present it will suffice to call attention to the well-known fact that with all the higher forms of animal life this is without exception accomplished by means of sex differentiation.

We are now face to face with one of life's mysteries and consequently one of the most intricate problems of

* I wish to acknowledge an indebtedness to my son, Dr. Ralph Wallace Reed, of New York City, for valuable suggestions as to the manner of presentation of this paper, and also for considerable assistance rendered in the preparation of the Manuscript.—T. E. R.

biology—this question of sex, its manifestations, its determination and its origin. Notwithstanding the now well-known fact that next to the motive of self-preservation the motive of self-perpetuation may be recognized as forming the principal basis of activity in all organisms, and even in man himself, sex manifestations were not for many centuries thought of as constituting any problem whatever. These phenomena were in fact like the regular succession of night and day, so obvious and so constant that they were taken for granted.

With the problem of the origin of sex, other than in the consideration of what it may have to teach us in respect to the determination of sex, we will not deal. It is intimately connected with the question of the origin of life itself, and probably will only be completely solved with the solution of that problem. Could we correctly define just where and why sex differentiation originated, the question as to what determines its manifestations would no doubt be no longer one to which an answer is wanting.

Elaborate investigation of the methods of reproduction in the primitive forms of life have been of use in clearing away many of the misconceptions which have surrounded this problem, but their value has been largely of a negative character—they have eliminated for us the non-essentials. Many of their results have been so remarkable, and at times such strong experimental evidence has been brought to the attention of the scientific world that the problem seemed to be near a solution. When the results which were secured from nutritional control in the *Daphnia* or the Lepidoptera were sought with the higher animals, or man himself, they have almost without exception been found wanting. All these theories and experiments have eliminated many factors of the equation. They have placed sign-boards across many blind passageways which were at one time thought to lead out of this labyrinth, warning us that here is no thoroughfare, or that here we cannot go far before we will find ourselves face to face with another barrier; or that if we follow this path we will only travel in a circle, and arrive again at our starting point.

This question, constituting one as it were, on the borderland between the known and the unknown, has been a fertile field for charlatanism. Where the light of the known blends with the darkness and mists of the unknown, there the ignorant, feeling much at home, pitch their tents. Yet, notwithstanding this, very many scientific men have not hesitated to approach the prob-

lem. Their efforts range from the expression of the merest opinion on the subject to the construction of the most elaborate hypotheses based upon patient experimentation. But the hypothesis has yet to be announced that will account for all of the observed facts, or accounting for the facts will yield any results when put into practice.

As a consequence of all this, what is, to-day, the attitude of the scientific world toward this question? Some hold that it is in all probability insoluble; others hold that we may in time discover the factor which determines the sex, but that any control of sex will no doubt be impossible. Beard thus indirectly expresses his opinion of all schemes for the control of the sex in offspring. He says: "Any interference with or alternation of the determination of sex is absolutely beyond our power. To hope ever to modify its manifestations would be not less futile and vain than to imagine it possible for man to breathe the breath of life into inanimate matter. For the workings of nature in sex merge into her revelations of life itself."* Others believe that we already know what determines sex and that we have now only to overcome the difficulties which present themselves when we attempt its control, while still others hold that the whole question is one that is yet to be answered. They do not deny the possibility of finding an answer, but they believe that as yet nothing is so positively known that we can afford to dogmatize. With this last view of the question we are inclined to agree. One thing is certain: no hypothesis has yet been advanced that will satisfactorily explain all of the observed facts. There are always residual phenomena that refuse to serve as links in the chain, seemingly so strong and well connected in parts. We will not in this paper enter into the history of these investigations, or theories. In many theses it is well treated as an introductory to the author's own views on the subject, and to these we refer any who may be interested in the history of the problem. The compass within which we wish to keep this paper prevents us from following this method. However, when we are able to gather any lessons from the results of others we will not hesitate to do so. Investigators here need not suffer for want of a literature. Burdock has compiled a list of some one thousand works on the subject.

The reader who has followed us thus far if he had not already preconceived opinions on this matter has

* Zoologische Jahrbucher Anatomie und Ontogenie, Vol. 16, 1902.

now, perhaps, from what we ourselves have said, acquired somewhat of a prejudice against considering seriously the claims of any one who may think he has solved the riddle or even has something new to say upon it after so many have occupied themselves with it without marked success. However, we will ask him, if this is the case, to suppress for the time being these very natural prejudices and follow us to the end of this paper. When this is done we feel that if assent is not given to the conclusions drawn from the facts which will be adduced, it will at least be admitted that the hypothesis advanced accounts for the facts as well as many others which have been promulgated within the last fifty years; and furthermore, as far as we are aware, the main details of the theory have never been anticipated.

Hipocrates was one of the first to express an opinion on the determination of sex. He was a physician and since his time it has been a problem that has appealed especially to this profession. It will here be considered largely from the standpoint of the physician.

Let us briefly consider some of the different theories which have been advanced: what may be said in their favor and what may be urged against them. Thus by a process of elimination we may narrow our inquiry down to comparatively restricted limits. While it would be interesting to do so we will not attempt here to consider the speculations on sex published in the middle ages, or during the periods of Greek and Roman speculative philosophy. Their ideas on this, like those they held on many other natural phenomena, were based on no scientific foundations and at the best were usually guesses—excellent guesses sometimes, but still after all only guesses.

First we have those who hold that the sex is a definite property of the ovum, that it is male or female from the very beginning of its existence, and that the whole function of the spermatozoa is one of fertilization or supplying the proper stimulus to the ova. The part here played by the spermatozoön is thus a minor one even in the higher animals, and it is pointed out that in the lower forms of life fertilization often takes place without any fusion with the spermatozoön, thus proving that the conference of sex is not one of its functions at least. We would thus never be able to control the sex unless we could exercise a choice in the selection of a particular male or female ovum. Even supposing that we could in some manner devise a test for sex in the ova the fertilization of selected ova

would present difficulties which, in the higher forms of life at least, would be impossible to overcome. Nevertheless the fact that this hypothesis offers us no hope for the control of sex is no ground for its rejection. There is something to be said in its favor. It is supported by good authority, by its accounting for parthenogenesis, and by the fact that sex is one of the earliest characteristics to be distinguished in the embryo.

To digress for the moment, let us sketch the different methods of reproduction. We are compelled in the beginning to recognize the fact that with many forms of animal and plant life there is no differentiation of sex whatever. In the protozoa we have reproduction by the simple act of fission or division. This is the manner of multiplication of all simple animal cells; it is, in short, either a direct cell division or karyokinesis. Then we have a budding or gemmation which is the common method of reproduction with the polps and in many infusorians. Next a very free bud formation, known as endogenous or spore formation as with the *arcella*. When we reach the metazoa we have a borderland process between sexual and asexual reproduction. Here the distinction between body cells and reproduction cells is more marked. Now the distinctive characteristic of sexual reproduction is the existence of two forms of cells; one form being fertilized by the other. The facts of sex evolution would thus seem to favor the above hypothesis. It should be remembered, however, that these dimorphic cells may be produced from male and female individuals as is the case with the higher forms, or they may as with some of the lower forms of life be produced within the same organ of the same individual *but at different times*. This point we will later consider in greater detail.

The ideas of Beard, who is probably the ablest of the upholders of the thesis that sex is a property of the female germ alone, may be thus summed up. He holds that the male element has not the slightest influence in determining the sex, it only exercising the function of fertilization or in other words originating the amphimixis. He believes that sex is a function of the egg itself, and that with a given ovum there is nothing that can alter the sex that is predestined to arise from it. Sex therefore is not determined at the moment of fertilization but a long time prior to that. The doctrine that the sex of the embryo may be influenced through the mother after development has commenced, although never possessing much scientific standing, is entirely

discredited by these investigations.* Before leaving this phase of the question it might be well to mention another point at issue. Some investigators have held that fertilization itself has something to do with sex, as it was at one time thought that fertilized eggs in the bee could only give rise to females. Beard denies this, however, and holds that both male and female can be produced parthenogenetically.

We believe with Beard that it can be shown that sex does not arise subsequently to impregnation, and this is practically the consensus of scientific opinion to-day, but we hold that the view which makes a definite sex distinctively a function of a particular ovum existing as such for an indefinite period prior to impregnation, is one that at the best rests upon a hypothetical basis. Even if the ovum be one which undergoes development without fertilization it cannot be shown that it, from its origin, must necessarily have been male or female, and that prior to the beginning of its development it could not have been as it were in states of equilibrium or fluctuation—its sex subject to determination by some slight subsequent influence. Or in instances where development depends on fertilization, since the sex cannot be known until after some degree of development has proceeded, how can the influence of the spermatozoa be ruled out?

But, it may be asked, is there any possibility that the sex of the ovum can be known prior to fertilization? We have been able to find no experimental evidence tending to show that it can. Minot* says in this connection, that there is no material basis of sexuality in the sense that there is any visible sex male or female substance (referring to the primitive cells) known to the biologist. He rather considers the male and female cells as essentially the same except that in the male cell there is an over development of the nucleus and in the female cell an over development of the protoplasm. The ova resembling old cells and the spermatozoa resembling young cells. He further remarks that we can ascertain the sex of a genoblast by observing its history and not by any direct test. It is probable, he says, that the male or female sexuality is an intracellular relation of parts, or some modification of the interplay of forces within the cells, and he believes that for the present this view

* See *Zoologische Jahrbucher, Anatomie und Ontogenie*, Vol. 16, 1902.

* *Human Embryology*, 1902.

must hold against the opposite one that there is a male matter and a female matter.

We will not consider in detail such theories as the influence of suggestion in determining sex, the time of day of conception, the time with reference to the menstrual month, the relative ardency of the parents, the ability of the more passionate parent to stamp the sex, the theory which holds that ova of one sex are produced one month and ova of the opposite sex the next, alternating, and thus maintaining an equilibrium between the sexes; or psychological theories which hold that a mother of strong character produces male offspring and vice versa. None of these ideas with the exception of the one which refers to the time of impregnation with respect to the menstrual flow have ever enjoyed much scientific standing. Some of them, as in the instance where sex is referred to the alternate monthly generation of male and female ova, may be readily disproved, hence they never obtain much vogue, while others, because the determining factor is conceived to be one which after all is relatively so indefinite, can never be disproved to their originator's satisfaction or proved to the satisfaction of any one else.

The possibility of modifying or developing characteristics by breeding has long been recognized by stockmen. Since the elaboration of the doctrine of evolution this method of improving a strain has been more carefully worked out and carried to extremes not before thought possible. This ability to secure desirable qualities in offspring by selection of parents possessing these qualities naturally led breeders to hope that they might in time be able to produce a desired sex in offspring by selecting the parents from strains in which the tendency to produce one sex or the other predominated. Copeman and Parsons attempted to systematize this method, but without apparent success.* Their failure might have been predicted. It was not recognized that sex differs very materially from other characteristics. Sex admits of but two variations, any other characteristic admits of variations which may be considered as almost infinite, and the very fact of breeding for a certain sex presupposes the admission as a factor in the problem, of the sex element opposite to the one desired in the offspring. This necessarily counts half, so we cannot hope for a preponderance of

* For an account of their experiments see "Observations on the Sex in Mice," Copeman and Parsons, Proc. Royal Soc., Vol. 73, pp. 32-48.

one or the other influence in the parents, or, the conditions being of course the same, in the grandparents, and so on back. Thus we see that as far as hereditary influences are concerned, by the very nature of things, there must be a tendency toward the maintenance of an equilibrium between the sexes.

PART II.

DARWIN says in respect to the bearing natural selection may be considered to have on this question: "Suppose the case of a species, which from unknown causes produces an excess of one sex, say males—an excess of males being superfluous and useless. By natural selection could the sexes be equalized? We may feel sure from the fact that characteristics being variable certain pairs would produce a somewhat less excess of males over females than would other pairs. The former supposing the actual number of offspring to remain constant would necessarily produce more females and would therefore be more productive. On the doctrine of chances the greater number of the offspring of the more productive would survive and these would inherit a tendency to procreate fewer males and more females. Thus a tendency toward equalization would be brought about." He apparently does not advance this hypothesis very confidently, and later he evidently felt it would require considerable modification, for he says: "I formerly thought that when the tendency to produce both sexes in equal numbers was advantageous to a species it would follow from natural selection, but I now see that the whole problem is so intricate that it is best to leave its solution to the future."*

Before reviewing Starkweather's hypothesis, which will be discussed in greater detail, attention will be called to a sex theory which a few years ago attracted considerable notice. The late Prof. Schenck held that in order to produce male offspring it is necessary to alter the diet of the mother previous to conception, selecting nitrogenous substances and excluding carbohydrates. The urine should be examined for sugar by a series of very delicate tests. When all sugar has disappeared impregnation should be allowed, but the diet should be continued for about eight weeks afterward, when, he says, it may be gradually altered. If

* "Descent of Man," Chapter VIII.

a boy is desired the urine must be entirely freed from even the slightest trace of sugar before conception. He says: "The condition of a woman in a well regulated married state, when, as we will suppose, five or six girls are born, must be supposed to be of the kind that departs more or less from the normal." He also remarks that no influence can be exerted if female offspring are desired. On reading Prof. Schenck's book it immediately occurs to one that if these contentions are true a woman afflicted with diabetes mellitus, in which disease varying amounts of sugar are constantly being excreted, would necessarily always give birth to girls. This is not found to be the case. The author, however, anticipating this objection, advances this rather unsatisfactory explanation; he says: "Notwithstanding the high percentage of sugar excreted in the case of a woman suffering from diabetes, female offspring do not necessarily appear, because in the slighter cases of this disease the normal metabolism can be considerably improved." Without depreciating in the slightest the patient investigation evidently given by Dr. Schenck to this subject, we feel that this method considered merely as a hypothesis is about the least plausible of any of those we have met with. On the other hand we do not believe that the clinical evidence he presents is extended enough to justify his conclusions.

Dr. Napheys held, with M. Thury, whose name is most prominently connected with this view, that the time of conception with respect to the menstrual month is an important factor in the determination of sex. He states that the queen bee lays female eggs first, hens are also said to do this, although Albin's extensive experiments with poultry would hardly seem to justify this conclusion.* The method was also supported by the authority of Düsing. Some stockbreeders claim to have had considerable success in following this rule. Breeding mares late in heat when male colts are desired. Schroder has investigated this, however, and affirms that he has never been able to confirm M. Thury's theory with the human subject.

The following somewhat hazy hypothesis has lately been advanced by a French writer on the subject.† What is intelligible in the theory seems to partake largely of Starkweather.

He believes the ova and spermatozoa express the

* *Centralblatt fuer Medicinische Wissenschaft*, 1868.

† "Qu' est-ce Qui Determine Le Sexe?" A Van Luit. Paris: 1902. Bailliere et Fils.

extremes of fine cellular differences. They typify in themselves the psychological and somatic differences between the adult male and female organism. He also holds that there is an antithesis between the germ cell born by an individual and that individual. In brief the spermatozoa are essentially female, and ova male, thus each adult organism typifies the primitive hermaphroditic unity of sex, which he postulates. This being true, he believes that if a relatively feeble ovum be fertilized by a vigorous spermatozoon the qualities of the spermatozoon will be dominant, the offspring resembling the father, but of the female sex. Sons are the result of vigorous ova fertilized by feeble spermatozoa. He holds that the somatic cells must balance the sex cells and therefore they will be female and the offspring will be male but resembling the mother.

This résumé of a few of the principle sex theories will be concluded with a brief consideration of the Starkweather hypothesis, which is perhaps one of the most plausible of the many theories that have been advanced.*

The law which he believes he has discovered he briefly sums up in the following words: "Sex is determined by what I shall designate as the superior parent, also the superior parent produces the opposite sex."

While there may be much difference between two individuals of the opposite sex, he holds that sexes are equal in the aggregate, male equaling female, as true physiological equivalents. He further says that, with reference to individuals, "superiority" means "anything which tends to increase functional energy in any part of the system," and that "the superior germ rules, as superiority is sure to do wherever it be placed, and outbalancing the other, turns the scale of sex, but subject to the unvarying law of opposites which we conceive to be the principle of universal equilibrium, produces its opposite, hence if the mother be more highly endowed, or even but temporarily more favorably conditioned than the father, the offspring will be of the male sex and endowed with more of the mother than the father. The converse of this will of course obtain, and a superior father on the same principle will beget a daughter. The theory may appropriately be designated that of 'superior opposites.'"

It will be readily seen that this hypothesis accounts remarkably well for the general equality in numbers between the sexes. A superior father, young, and the

*"The Law of Sex," George B. Starkweather, London, 1883.

chances for life good, produces daughters, but as he grows older, passing the prime of life, and his wife, whom we will assume is some years younger than he, as is often the case, approaches her prime, she rather than he stamps the sex of the children, producing sons. Anything which might throw one sex of a species below par and thus threaten a disturbance of the balance is compensated for by the consequent ability of the superior parents to stamp the future offspring with the opposite sex. Leaving all secondary sexual characters out of consideration it will be conceded that the male or female of a mated pair run equal chances of possessing those qualities which confer superiority.

Starkweather further says: "That there exists a law of equilibrium in regard to sex as in all of nature's operations is a fact upon which I have insisted. . . . It is no mere assumption that there is a self-adjusting principle connected with sex, for it is a fact as visible as it is indispensable and immutable. Its workings are to be seen on every hand as easily as the vivifying effects of the sun's rays upon the face of nature. It must be so or the sexes would not show the invariable tendency toward equilibrium throughout the world as they now do." After a discussion of numerous sex theories he says that he soon learned to test the truth of any of these theories by ascertaining whether or not they contained any principle of balance. It will not be necessary to follow Starkweather through the detailed enumeration he makes of the qualities he considers superior and inferior. He lays stress on cerebral development, nervous energy, will, temperament, physical development, and nutrition; intelligence, facial features, etc.

The first objection to be urged against this theory is the one already stated as applying to many others; that is, so many of the factors are relatively very indefinite. Hence there would always be room for considerable difference of opinion as to what would constitute superiority in any particular instance. In man we should be able to recognize superiority and inferiority more easily than in any other animal, because we are more familiar with the factors involved, but when we take any particular mated pair we find that in a great majority of instances any factor denoting superiority, for instance in the male is offset by one denoting inferiority; or superior traits in the female are met or contrabalanced by other superior traits in the male. Had the originator of this theory taken one or two factors and been content to rest his hypothesis

on these, there would not have been so much room for a difference of opinion, but he evidently found early in his inquiry that no limited number would prove sufficient; he was therefore obliged to greatly enlarge his list of determinants running the whole scale from the lowest physical to the highest intellectual qualities. Now a state of things is reached which renders it easy for any upholder of his theory to find in any particular case plenty of evidence for it, but there is also the opportunity for any one so inclined to dispute almost every argument adduced.

The second objection to this hypothesis is one based on simple observation. Almost every one can note among their acquaintances families where girls or boys alone have been the rule. Then perhaps a child of the opposite sex makes its appearance without any obvious change of superiority between the father and mother. There might be room for a difference of opinion as to which of the two parents was originally the superior, but there cannot be any room for difference of opinion as to the fact that there has been to all appearances no superiority alternation.

Starkweather holds that his theory will apply to the whole animal kingdom as well as to man. Here he must encounter another objection, for in many species one sex is immensely and constantly superior to the other. In the course of a few years a stallion may be bred to a great number of mares. He is in all probability a superior animal to every one of these. He is in fact selected as a sire because of his superiority in every respect to the ordinary run of horses, yet the sex of the offspring varies. Many other examples of this might be cited, as in the *Arachnoideans* where the females are often very superior and with the *Bonellia viridis* there is a great difference in size, the female being markedly the superior.*

Starkweather gives numerous rules for the acquirement of superiority by one parent for the purpose of determining the sex of a child yet to be conceived. Now the whole trend of modern thought on this subject of heredity goes to show that the germ plasma is not entirely uninfluenced by any acquired characteris-

* Beside those species with which one sex is constantly superior to the other, there are instances where, as with polygamous species, a number of females are ruled by one male, who for a long period of time kills or drives away any younger males aspiring to the leadership. Notwithstanding the leader's proved superiority, just as many males are born. The American bison is a case in point. This fact would also account for the majority of females noted in some species.

tics in the parent organisms is but very slightly so. All these methods, recommended as favoring the determination of sex in the germ cells by the acquirement of superiority on the part of one or other of the parents, such as exercise, rest, feeding, fasting, fatigue, a certain mental state or attitude, produce at the best but the merest temporary somatogenic variations, and it is consequently hardly reasonable to suppose that they exert any influence whatever upon the germ cell since it has been shown many times that characteristics acquired by the parents for generation after generation do not make their appearance spontaneously in the offspring. Weismann says in this respect: "The transference of sex has usually been looked upon as an act of transmission. This cannot be the case, inasmuch as every germ plasm contains the primary constituent for both sexes, and the process of transmission itself has evidently nothing to do with the determination of sex. As already mentioned, it does not by any means follow that because a child is a female its primary and secondary sexual characteristics will resemble its mother's. This indeed has long been known, but has not led to the general recognition that sex is not transmissible at all, and that on the contrary the primary constituents of both sexes are passed on from both sides."*

The last objection we shall urge here against the Starkweather hypothesis will be one which also will serve to test many other theories. This is simply the birth of twins of both sexes. The term "twins" is used here in its popular meaning of two children born of the same mother as a result of the same pregnancy. True twins are always conceived at the same time, originate in the same ovum, and are always of the same sex, but two ova may be impregnated at the same time or at different times varying from twenty-four hours to one month or more apart and yet the children be born at the same parturition constituting not true twins but rather double births. These may be of the same or of different sexes. Where there is the fact of a double birth it is quite possible for the two children to possess different fathers. Instances of this have been recorded in medical literature. Now where we have a male and female child conceived, we will say scarcely twenty-four hours apart, we must suppose under the Starkweather hypothesis that the superiority

* "The Germ Plasm." A Weismann. Scribners' Contemporary Science Series, 1898.

of the parents has been subject to a very rapid alternation.

Here it might be well to consider this subject of twins in greater detail, as it has some important bearing on the discussion to follow. Gould and Pyle quote Hippocrates' observation that "twins are always the result of a single coitus and that each infant has a chorion," with the comment that both kinds of plural gestation, monochorionic and dichorionic, were known to the ancients.* This view of Hippocrates cannot be corroborated. Where twins are the result of one coitus they are always of the same sex and are enclosed in one chorion. It will be found in fact that there is some confusion and difference of opinion existing even to-day among physicians upon this matter of twins. It is difficult to see why there should be when there is no material disagreement among the authorities. Edgar has well summed up the matter in his *Practice of Obstetrics*. He says: "Twins may be derived from one ovum from each ovary, from two ova from the same ovary or from a double ovum both nuclei being fertilized, or from a division, which takes place in the blastoderm giving rise usually to conjoined twins." He further says that twins originating from a single ovum are always of the same sex. He thus describes the arrangement of the membranes: "The decidua vera is invariably single, the decidua reflexa is double when the ova are attached to parts of the uterine wall widely separated. The chorion, since it takes its origin from the zona pellucida, is invariably single where the twins are derived from two nuclei within a single ovum, but double when they originate from separate ova. Originally the amnion is always double for it is derived from the embryo although before delivery there may be an absorption of the septum between the products of conception. Primarily the placenta is double, for each foetus produces its own allantois and the placental region resulting therefrom. In the case of twins resulting from different ova the placentæ may remain separate but fusion generally occurs. There is, almost without exception, an anastomosis of the vessels of the placentæ of twins from a single ovum, hence if there are two distinct ova there may be expected two sets of membranes, while in the case of one ovum there will be a double amnion with a single chorion and placenta. In a very rare number of cases only one amnion has been found, but the

* "Anomalies and Curiosities of Medicine."

partition between the two had probably been absorbed."*

In the course of a series of controversial letters published in the *Medical World*† a few years ago, a number of physicians quoted their personal experiences as tending to show that twins of different sexes may possess but one placenta. We pointed out that in all probability had a closer examination of these different placentæ been made more or less distinct evidence of the fusion of two placentæ might have been observed. One case was quoted in which the attending physician stated positively that there had been but one placenta although the twins were of both sexes. We went to considerable trouble to procure this placenta and found on close examination undoubted evidence of the fusion of two placentæ. We have attended a considerable number of twin births but have never found an exception to this rule. Twins proper are *always* of the same sex, nourished through one placenta and enveloped in one chorion. The two or more children are very often counterparts of one another, "as alike as peas in a pod," not only in appearance but in temperament. Even mothers must sometimes improvise marks of distinction. Not only are they alike physically but the bond of sympathy is very great. It has been noted that when one falls ill the other is likely to become similarly afflicted. All other so-called twins are double pregnancies, they may be of the same or opposite sex, but are conceived at different times, hours, days, weeks, or in rare cases even months apart.* There are thus a number of reasons for believing that homologous twins are invariably conceived at the same time. It is important to remember in this connection that while a developing ovum may possess a double primitive trace, it has never been fertilized by more than spermatozoön. An ovum is often attacked by several spermatozoa, but as soon as one succeeds the others give up the struggle as far as that particular ovum is concerned. It is thus manifestly impossible that one division of the egg might be fertilized by one spermatozoön and another spermatozoön happening along later succeed in fertilizing the other division. *Conjoined twins are therefore the result of a simultaneous fertilization.*

* J. Clifton Edgar, "Practice of Obstetrics."

† *The Medical World*, Sept.-Nov., 1902.

* The children are born at the same time because when the elder arrives at full term the labor breaks up the fastenings of the other, its birth soon following.

George Jackson Fischer thus sums up what teratology has to teach us. He says: "For the past quarter of a century the writer has taken pains to carefully examine several hundred specimens of human double monsters and even larger numbers among the lower animals which are to be found in the pathological museums in the principal cities of the United States and he is able to state that he has never seen an exception to this law. The literature of teratology contains reports and references to no less than five hundred cases of human double monsters and also great numbers belonging to the beasts and birds and there is not a single modern instance in which the male and female organs are found to coexist. . . . It is safe to say that duality of sex will never be seen in a double monster."* Hirst and Piersol, who have made such valuable contributions to teratological literature, confirm this observation.*

The theory that in conjoined twins there takes place a fusion between the two individuals after development has begun is one that is no longer tenable. A consideration of the process of development combined with a review of reports of dissections made from time to time will show why this is so. At any rate the view is now general that conjoined twins are the result of an incomplete fission of a primitive trace rather than a subsequent fusion of two embryos.

It could perhaps be held that this demonstration of a unity of sex in individuals whether united or not developing from the same ovum does not prove that sex depends on the time of fertilization, since the sex may be the same for the same reason that other characteristics are similar. With ordinary homologinuous twins this similarity, as we have pointed out, often exists, and it is reasonable to suppose that children springing from the same ovum and fertilized by the same spermatozoon should be similar. *But are they always similar? In point of fact often they are not.* No doubt many physicians could give an instance where children of the same sex, inclosed in one chorion and nourished through one placenta displayed even at birth physical differences and very early manifested marked temperamental dissimilarities. Perhaps the best examples of this can be noted in conjoined twins, including here not only children joined at some part of their bodies

*A Reference Handbook of the Medical Sciences, 1889. Subject, "Teratology."

*"Human Monstrosities." Philadelphia, 1891-3.

by a band of more or less breadth and variety of tissue organization, but also, as in those cases, exemplified in the Tocci brothers, showing a complete fusion of one part of the two individuals. There have not been many instances where children born thus have lived long enough to be carefully examined or their mental and physical development watched. Nevertheless there are a few cases of this kind recorded in medical literature and in two or three instances the history is a fairly complete one. There can be no doubt but that these conjoined twins are often quite dissimilar *in everything but sex*. In the very well-known case of the Siamese twins, Chang and Eng were said to have been temperamentally very similar, liking and disliking the same things and never disagreeing in any way, but physically there was considerable difference between them, Eng being much stronger and possessing a decidedly better constitution than Chang. The North Carolina sisters, joined back to back, were born of negro parents and lived to adult age. They were said to have been remarkably different in temperament. The twins known as the Hungarian sisters were born in 1701. They were said to have been well formed and of pleasing appearance in every way except that they were united at the second sacral segment. They lived to be twenty-three years old. As might be expected they suffered from the infectious diseases, measles and smallpox, at the same time, but other diseases they had separately. Judith was not as strong as her sister Helen. Much has been written about them, but their mental history is not as complete as could be desired. The Tocci brothers, born in Italy, while possessing one body from the waist down, do not resemble each other very closely in conformation of the head and facial features, while there is quite a contrast between the two in mind and character. Dr. Harris says that such twins are never on exact equality of physical vigor. He further says: "United twins rarely bear a strong likeness to each other and in this respect are quite in contrast to normal twins and triplets of the same sex. . . . As a rule they are unlike in physical conformation, in measure of health and strength, in taste, and in mental characteristics."*

All this would seem to show that the conception that sex may be considered in the same category with other inherited qualities such as the color of hair, conforma-

* "The Blended Tocci Brothers and their Historical Analogues." Robert Harris, A.M., M.D., *American Journal of Obstetrics*, 1892, page 460.

tion of features or physical peculiarities has been a fruitful source of error and the germ of much useless speculation.

The view that the mammalian ovum is not primarily male or female but that it possesses equal capabilities of developing in one direction or the other is not uncommon. The ovum is thought to be in all probability in a state of delicate equilibrium so that a very slight influence may serve to turn the scale for the male or female sex as the case may be. Both sexes are thus potentially existant in the germ cell. There are a number of facts which may be adduced in support of this view. Some lower forms of life manifest a true hermaphroditism; tadpoles often seem to linger long in this neutral state before they finally take on definite male or female characters, and in the oyster the same set of organs fulfils both functions but at different times.* Darwin has called attention to the interesting fact that variations of some secondary sexual characters as a peculiarity in the growth of the beard may be inherited from the grandfather through the mother. This transmission of a peculiarity of a secondary sexual character through a parent of the opposite sex proves that secondary sexual character of one sex are latent in the opposite sex.* The organs of generation of each sex in themselves show many striking similarities, each peculiarity of one set having its analogy in the other. This fact has been long noted. Next it has been shown that secondary sexual characters depend very largely upon the integrity of the primary sex organs. Also attention has been called to the fact that after castration and in old age the secondary sex characters of the opposite sex are often developed. Furthermore organs and functions belonging more particularly to one sex exist in a rudimentary form in the opposite sex.

We thus see that while the primary sexual characteristics of one sex have their analogies in the opposite sex, they being in fact practically the same but functioning in a different manner, a whole host of secondary and tertiary† sexual characters of one sex are either latent

* "The Evolution of Sex." Geddes and Thompson. Scribners' Contemporary Science Series.

* For a discussion of the relations in general between heredity and secondary sexual characters, see Darwin's "Animals and Plants Under Domestication," Chapter XII.

† By "tertiary sexual characters" is meant those characters manifested only in the aggregate, such as the greater height of men, the greater weight, in proportion to size, of women, etc. The term was, we believe, introduced by Mr. Havelock Ellis.

rudimentary or manifested in the opposite sex. With these facts before us is it too much to suppose that the ovum is potentially both male and female? Weismann assumes the sexual determinants to be double, consisting of two groups of biophores and in all sexually dimorphic organisms he believes that the germ plasm must contain other double primary constituents to account for the secondary sexual characters. Now whether this is so and the germ plasm be thus truly hermaphroditic or whether it is neutral is not of special moment here, but the fact that it originally is in a state of equilibrium and neither distinctively, or at least continually, male or female is extremely important. Weismann, referring to this point, says further . . . "we are ignorant of the forces and substances here concerned, but we at any rate know that the idioplasm of the primary germ cells in the higher animals is still capable of giving rise to either kind of germ cells and that the decision as to whether the germ cells will develop into ova or spermatozoa occurs at some early stage in embryogeny. In the eggs of the bee it takes place in the beginning of the embryonic development long before the first primary germ cell is differentiated, while in other animals it perhaps occurs at a later stage. The well-known researches of Siebold and Leuchart prove that at any rate in the case of bees this decision rests on the occurrence or omission of fertilization.* It occurs then at a time when the germ plasm which controls the new organism is constituted."[†]

In reference to hermaphroditism Geddes and Thompson, in their very interesting and suggestive work on the evolution of sex, say: "There can be very little doubt that hermaphroditism was the primitive state among multicellular animals, at least after the differentiation of sex elements had been accomplished. In alternating rhythms eggs and sperms were produced. The organism was alternately male and female. Of this primitive hermaphroditism there is probably more or less of a recapitulation in the life history of all animals. Gegenbauer states the common opinion in the following cautious and terse words: 'The hermaphroditic stage is the lower and the condition of distinct sexes has been derived from it.' Unisexual differentiation by the production of one kind of sexual

*Males being said to develop from unfertilized and females from fertilized ova. This has since, however, been denied.

† "The Germ Plasm." Weismann,

apparatus takes place at very different stages in the development of the organism and often when the sexual organs have a very high degree of differentiation. The first structural stage in the separation would probably be the restriction of areas in which the formation of two kinds of cells still went on at different times in one organism. In different individuals the opposite tendencies we have already spoken of more and more predominated till unisexuality evolved out of hermaphroditism.”*

The bisexual rhythm which is here hinted at will be referred to later, but the many excellent reasons there are for believing that this primitive hermaphroditism so common in the lower forms of life may be considered as constituting the chief sex characteristic of the germ plasm itself, should be held in mind.

Writers on the problem of the determination of sex have usually depended largely upon statistics showing the proportion of male and female births, with different classes or races, or in different districts during certain periods of time. From these they have drawn conclusions usually favoring their own hypothesis. It should be unnecessary to call attention to the unreliability of this method unless it is carried out with more thoroughness and followed up through a longer period of time than as far as we are aware any one has heretofore attempted. The statistical method here is subject to the same objection that may be urged against it as applied to any other problem. That is, it must be more or less limited to certain districts or countries and at least to certain periods of time. We know that there are some problems to which, from their nature, it may be applied even in a limited degree without feeling that it may be instrumental in leading us astray, but this question of the predominance of male or female births is not one of them. It is indeed doubtful if for every set of tables from one country showing a predominance of a certain sex, another series from another country showing a predominance of births of the opposite sex might not be adduced to offset them. Statistics have been brought forward to support the most widely divergent theories, some requiring a predominance of male births and others demanding a predominance of female births for their support. While a minority may thus dispute this question, the belief that there is a continual tendency

* "The Evolution of Sex." Geddes and Thompson. Chapter VI.

toward the maintenance of an equality in numbers between the sexes is prevalent not only among biologists and sociologists, but among mankind in general. It may be considered as almost self evident that there is something which maintains this balance, for if there were any definite factor (such as nutrition) creating a tendency in one sex to predominate, it is extremely doubtful if, acting over extended periods of time, or being augmented or diminished under certain conditions, its existence would not have been recognized long ere this.* Darwin held that there is undoubtedly a tendency toward the maintenance of such a balance, and gave us a tentative explanation of how it might be accomplished through the agency of natural selection.

Starkweather collected a number of facts bearing upon this phase of the problem and his conclusion was that there is undoubtedly constant tendency toward the maintenance of an equality in numbers between the sexes. He does not weary of insisting that this natural maintenance of a balance is one of the strongest arguments in favor of his hypothesis. While several reasons have been cited why we cannot subscribe to the theory of conference of sex, by superior opposites, he is undoubtedly correct in his contention that a balance in numbers between the sexes is in general maintained. It should now be conceded that at least as far as mankind is concerned we are safe in assuming this to be so. The question next arising is whether or not there is any other method by means of which this balance could be maintained. We believe that there is one and only one.

PART III.

THE opinion that sex is determined by the *time* of conception or impregnation, has already been expressed. The implication is, of course, that this occurring at one time the offspring will be female, and at another time, male. Let us suppose merely for the sake of an illustration (for we do not believe either of these hypotheses tenable) that girls are conceived one hour and boys the next, or that one sex is the result of impregnations taking place during one menstrual month, and the opposite sex the result of impregnations taking place during the succeeding month. The sex thus

*Mr. R. C. Punnett, after a series of comparisons of male and female birth rates in the slums of cities with births recorded in Burke's Peerage, concludes that nutrition has little or nothing to do with determining sex in man. See Proc. Cambridge Philosophical Society. Vol. II., pp. 262-267.

depending upon regularly alternating, equal time periods.

Other things being equal, it now follows that the periods of time during which individuals of one or the other sex may be conceived, being equal, the sexes in the aggregate must maintain approximate equality in numbers. But from the same reason a continual fluctuation must be expected; at times a greater number of boys will be born, again the girls will predominate, the very law of chance which maintains an approximate equality between the sexes preventing, except for very short periods of time, an actual equality. To make this point clearer, let us suppose that a coin is tossed into the air. At every toss the chances of its falling "heads" or "tails" are equal. If the experiment is continued, one or the other will predominate, but in time this lead will be gradually lost, and an exact equality will be reached. This equality will not be long maintained; the other side of the coin will soon show the greater number of times and after predominating for a time the process will be repeated with the same result. There is thus a continual fluctuation from one to the other side of an equality or equilibrium not unlike the stroke of a pendulum. Now it is evident that whether one or the other face of the coin is found in the lead will depend altogether on when the experiment is discontinued. In the same way, there being an equal chance for the conception of males and females, it is also evident that a predominance of the male or female sex will depend altogether on when and where the statistics are taken.

We have seen how necessary it is that any theory of the determination of sex explain satisfactorily this general equality of the sexes. It has also been shown that if we suppose the sex distinction to depend upon the time of impregnation, this equality is accounted for. Looking at the question from this point of view, we conclude that in the first place should the time of impregnation be a determining factor, it could not, for obvious reasons, depend upon any artificial division such as the hour or week, except in so far as this artificial division expressed some definite relation to a natural period of time. We must, therefore, look to some natural time cycle in the external world, such as the regular alternation of day and night, the lunar month, or the year; or we must attempt to determine whether or not sex is influenced by the time of impregnation, in its relation to some natural cycle of change within the organism itself, such as rest and fatigue, hunger and satiety, wakefulness and drowsiness, the regular period of digestion, excre-

tion and secretion, the rise and fall of sexual desire, the anabolic and katabolic cycle through which every organism is constantly moving; or whether by its relation to that great cycle in women, the menstrual month. Finally we must consider whether or not sex may be determined by any periodic change with the germ plasm itself.

We may first eliminate the year as being too long a cycle to consider; furthermore, experiments devised to show any possible effect of temperature on sex have yielded but meagre results. The lunar month must also be rejected as a factor in the determination of sex for the same reason; it constituting too long a period and thus failing to account for double conceptions or pregnancies where both sexes are represented. The theory of Düsing and Thury that sex is determined by the time of impregnation with respect to the menstrual crisis has also this same objection to meet. The unfavorable verdict of Schroeder has already been referred to. We will pass over one or two other objections which might be urged against it, merely stating however, that the view that it constitutes even one of a number of factors in sex determination has never received much support, and we do not know that it was ever applied to the human species with even moderate success. Impregnation with respect to the time of the solar day may be dismissed without much comment. It is probably not unreasonable to believe that the time of day may exert some influence in plants, but it has never been shown to exert any influence over animal life, as far as the determination of sex is concerned. The other factors, such as hunger or fatigue, or, in brief, any superficial somatic variation in the female organism as we have pointed out, in all probability do not exert any influence whatever upon the ovum; its essential characteristics, whether they be functional or structural, are laid down at its organization, and any variation of nutrition in the parent organism can have no effect upon them.

A summary of the results of our review of this subject is now in order.

What determines the sex has been the subject of investigation since the time of Hippocrates. Many of the older theories are entirely discredited by modern science. The view that the spermatozoön has any influence in the determination of sex has long been abandoned. It is now generally conceded that its function is only to originate the amphimixis. This view is held by Beard, Weismann and many others, while we are not acquainted with the papers of any biologist who holds the contrary.

Sex is therefore a property or function of the ovum.

Recognition of the anabolic character of female and the katabolic character of male organisms has led to the hope that sex might be controlled by regulation of the nutrition of the female parent. Experiments have been conducted with this in mind. Many results were negative. Others would seem to show that abundant feeding produces females. No results have followed attempts to determine the sex in the higher orders of life by means of this method.

A general equality which nature maintains between the sexes has been noted. Many theories of sex determination do not satisfactorily account for this. Starkweather takes this into consideration, but fails to meet the objection that his factors of superiority are relatively too indefinite. His theory also fails to account for twins of opposite sex.

Sex cannot be explained in terms of heredity alone. The idea, therefore, that certain parents tend to beget one or the other sex is to be distrusted.

Even were it admitted that the sex might be, to a certain extent, an inherited condition, modern views on heredity would forbid us to look for any method of controlling it, because sex, while in common with other inherited characteristics, is a function or property of the germ plasma, the inheritance of any acquired characteristics is, after all, very doubtful. If they are ever inherited it is only in special or rare instances or to a slight degree.

Therefore, all theories which would seek to control the sex by altering the physical condition of one or both of the parents may be dismissed.

In no ova which normally undergo fertilization has sex been detected prior to fertilization, while on the other hand embryologists have traced the existence of sex in the embryo back to almost the time of fertilization. Sex, therefore, is determined at or near this time.

However, since fertilization constitutes the crisis in the life of any particular ovum, it is not unreasonable to suppose that the sex of the future embryo is decided at exactly the moment of this crisis.

Shultz, as long ago as 1854, showed that irrespective of the number of individuals, there could arise from one egg but one sex.

Any egg, whether single or double, can be fertilized by but one spermatozoon, and therefore can be fertilized but once.

Conjoined twins, of whose origin from the same egg there can be no doubt, are always of the same sex. But

sometimes, notwithstanding the fact that they must have originated from a simultaneous fertilization, they differ remarkably in other characteristics.

From the wide distribution of tertiary sexual characters of one sex among individuals of the opposite sex; from the latent and rudimentary existence of secondary sexual characters of one sex in the opposite sex; from the marked analogy there is existing between the sexual organs proper of the two sexes, and, finally, from the fact that peculiarities of secondary sexual characters may be inherited from a grandparent through a parent of the opposite sex, we know that the male organism contains all the elements of the female and the female all the elements of the male. One is therefore justified in concluding that every ovum is primarily hermaphroditic, and the view that there are two kinds of ova, male and female, may be rejected.

Now to group our phenomena: *It is possible to have a double hermaphroditic ovum, capable of but one impregnation and capable of impregnation by but one spermatozoön, fertilized with a resultant development of two individuals, which, originating from two divisions within the same egg, fertilized at the same time, and acquiring sex distinction at the same time, may differ in other characteristics, but are always and necessarily of the same sex. There is but one conclusion to be drawn from this: Sex is determined at and by the time of impregnation.*

It has been shown that sex cannot be determined by the time of impregnation with reference to the month, menstrual or lunar, the year, season, week, day, or hour. Neither can it be determined by the time with reference to any somatic change within the parent organism. The lunar day, together with a possible sex alternation in the ovum alone remain to be considered.

While further reasons for our belief that this is the true solution to the problem will be stated in the next section of this paper, this will be concluded by the advancement of the hypothesis that sex is determined by the time of fertilization of the ovum with reference to a regular sex alternation (analogous to the katabolic and anabolic fluctuation in multi-cellular organisms) in the germ plasm itself. This rhythm is synchronous with the shortest of natural cycles, one complete cell cycle lasting about twelve hours, and, while not depending upon or perhaps exactly coincident with, at least corresponding to the upper and lower transit of the moon in somewhat the same manner as do the tides.

PART IV.

A NUMBER of years ago in a small volume, now out of print, this theory of the determination of sex was briefly outlined.* We called attention at that time to the importance of taking into account, in considering this question, the general periodicity of functional change throughout the organic world. We believe that sex is not so much a morphological as it is a physiological distinction. Theorists have devoted too much attention to structure and not enough to function. Now we know that in all organic life one may note through long continued and close observation, progressive change. This change is both structural and functional. It is progressive, but in any one direction it is not constant. There is a fluctuation backward and forward, a swinging of the pendulum from one side to the other of a mean, or a movement forward and a rest. For a structural change in a living organism to take place there must be a preceding functional change. This functional change in all probability arising from a structural change in some more basic tissue and so on back. It is thus impractical to attempt to disassociate structure and function. As we approach the simple cell they probably synchronize. At first thought or to the average man the morphological distinction between the sexes is the real distinction, but what we wish to call attention to is the underlying and essential distinction. We are not dealing in the obvious.

Of structure and function we may say that function is in general the most susceptible to variation. Its variation is at once the most dependent upon, and in some respects, the most independent of environment. There are some hereditary rythms of function in all life cells whether simply or complexly arranged, that seem to bear like the germ plasm, a charmed existence so that nothing short of the destruction of the organism itself suffices to break their continuity.

In the first part of this paper a number of reasons were given for holding the view, that the germ plasm is primarily hermaphroditic, containing all the elements of both sexes, that this condition is not lost even in the developed organisms; that morphological sex distinction is the result merely of a tendency on the part of the developing organism to functionate more actively in one direction than another; and that this tendency is conferred upon it at the moment of fertilization by the spermatozoon.

*Cyclic Law. T. E. Reed, 1897.

Now knowing that all functional activity displays a strong tendency to periodically fluctuate first to one and then the other side of a mean, it would be unreasonable to suppose that the germ plasm does not follow this universal law, or that it occupies a position of fixed equilibrium between male and female tendencies. On the contrary there is every reason for believing that the germ plasm is in a state of constant fluctuation from one sex extreme to the other. Structurally possessing the elements of both sexes, the ovum undoubtedly at one time by a slight functional change is actively female, but soon by an equal and opposite reaction functions as male. Attention has already been called to the very suggestive fact that this is actually what does occur in some hermaphroditic animals, in some, where the sex organs are the same, or in others where the same individual possesses both sets of organs the sperms and ova are secreted alternately as in the group streptoneura of the snails, and in oysters and clams. In regard to this fact Geddes and Thompson say: "If the hermaphroditism be very intimate, that is if the seats of ovum and sperm production be very close to one another it is not to be expected that the development of two kinds of cells will go on simultaneously. Such, indeed, would be a physiological impossibility. Antagonistic protoplasmic rythms may rapidly alternate, but cannot co-exist. Whether hermaphroditism be anatomically intimate or not there is throughout a tendency toward periodicity in the production of male and female elements."*

What could be more intimate than the hermaphroditism of the germ plasm of the ovum; and hence is it unreasonable to suppose that there must necessarily be a sex rythm in the germ plasm just as there is in other primitive hermaphroditic organisms? At the same time does it not seem vain for man to think that he may some day succeed in altering this hemaphroditic character of the germ plasm, basic as it is, conferring upon it a male or female sexuality, by some system of altering the nutrition or otherwise exciting variations in the parent organisms? As Weismann and his followers have long insisted, the germ plasm leads a charmed existence. We may destroy it, but we cannot change its structure or modify the interplay of forces within it.

It has been shown that sex is determined at the fertilization of the ovum. If we then admit this sex cycle of the germ plasm we must admit that the future sex

*Evolution of Sex, Chap. VI.

of the embryo depends upon whether fertilization takes place during the male or female period of the cycle. One thing we believe to be certain: if the determination of sex does not depend upon the time of fertilization or union between the sexes, it is as hopeless for man to think of controlling it as it would be for him to think of changing the orbits of the planets.

Since we cannot disturb this rythm of the germ plasm the only method of determining the sex of the embryo is to take advantage of it. We believe that a period of approximately twelve hours is occupied by the germ plasm in making one complete revolution from the beginning of the female variation through the male and back again to the female, each sex manifestation thus occupying a period of six hours. These periods constitute two phases of the complete cycle. They may approximately be designated the katabolic and the anabolic, from their probable embodiment of the great katabolic and anabolic distinction between the sexes in general, or the active and passive as typifying the distinction in activity between the two sexes, which can be traced with more or less facility in all bisexual organisms, or they may be termed positive and negative as representing the positive character of the male and negative character of the female.

Is this active character of male and passive character of female organisms a real or only an apparent distinction? We believe that it is a real one and a very basic one at that, having in all probability given rise to distinctions which are now more obvious. It is at least a phase of sex that has attracted the attention of biologists to a greater or less degree for some time. Thompson, in his *Zoology*, calls attention to it, and later, in conjunction with Professor Geddes, in *The Evolution of Sex*, dwells upon it at greater length. Thompson says in this respect: "Most animals are either males or females, the former liberating actively motile elements or spermatozoa and the other forming and usually liberating passive egg cells or ova."

Any one who has had the opportunity of observing the products of the male and female organism beneath the microscope needs no long description to emphasize this marked difference in activity. This writer further says: "All through the animal series from active infusorians to passive gregarines, from feverish birds to the more sluggish reptiles we read antithesis between activity and passivity, between the lavish expenditure of energy and the habit of storing. The ratio between disruptive (katabolic) processes and constructive

(anabolic) processes varies from type to type. We believe the contrast between the sexes is another expression of this fundamental alternative of variation.”* In Chapter II. of *The Evolution of Sex* many instances illustrating this important fact of the inherent activity of the male and passivity of the female are cited. They say: “The female cochineal insect laden with reserve products of the well-known pigment spends much of its life like a mere quiescent gall upon the cactus plant. The male on the other hand in his adult state is agile, restless and short lived. Now this is no mere curiosity of the etomologist, but in reality a vivid emblem of what is an average truth throughout the world of animals—the preponderating passivity of the females and the predominant activity of the males. These coccus insects are martyrs of their respective sexes.” In the fourth chapter of this same work where the question of the determination of sex is discussed this view is again emphasized. They continue “such conditions as deficient or abnormal food, high temperature, deficient light, moisture and the like are obviously such as would tend to induce a preponderance of waste over repair, a katabolic habit of body, and these conditions tend to result in the reproduction of males. Similarly the opposed set of factors such as abundant and rich nutrition, abundant light and moisture favor a constructive—*i.e.*—make for an anabolic habit of body and these conditions result in the production of females. This is not all, however. The above conclusion is indeed valuable, but it acquires a deeper significance when we take it in connection with the result of the previous chapter. There it was seen as the conclusion of an independent induction that males were of smaller size, more active habit, higher temperature, shorter life, etc., and that the females were larger, more passive, vegetative, and conservative forms.* Theories of inherent maleness or femaleness were rejected since practically nearly verbal: more accurately, however, they have been interpreted and replaced by a more material conception which finds the bias of the whole life, the resultant total activities to be predominance of the protoplasmic processes, either on the side of disruption or construction. This conclusion has still to receive cumulative proof, but one large piece of evidence is forthcoming, that

*J. Arthur Thompson—*Outlines of Zoology*, Chap. IV.

*In the course of the article on “Sex,” *Encyclopedia Britannica*, Thompson explains menstruation as the “means of getting rid of an anabolic surplus in the absence of its foetal consumption.”

namely of the present chapter. If influences favoring katabolism make for the production of males and if anabolic conditions favor females, then we are strengthened in our previous conclusion that the male is the outcome of predominant katabolism and the female of equally emphatic anabolism." It will be seen from this above quotation that these authors incline to the view that sex can be influenced by the nutrition of the parent organism. We have shown that at least as far as the higher animals are concerned this view is to be discredited. It is desirable that attention be more particularly directed to the rejection by them of all theories of "inherent maleness, or femaleness," and their advocacy of the view upon which this theory to a degree depends and with which we have attempted to impress the reader, namely that maleness is the outcome of katabolism and femaleness of anabolism, or as we have summed it up the essential distinction between the sexes is functional rather than morphological. This being the case, we should suppose that the sex cycle of the germ plasm might resemble in some way, or present an analogy to the anabolic and katabolic cycle which is constantly present in multicellular organisms. This is undoubtedly what really does occur and it is plainly unnecessary to postulate some mysterious interplay of cellular forces, when we have at hand this cycle of metabolism so plainly manifested in all animal life from the simple cell up to man himself; and especially when it has been shown that these conditions of anabolism and katabolism, passivity and activity, are so extremely typical of the sexes. The sex of the embryo is determined simply by the period through which the germ plasm happens to be passing when fertilization takes place. If it is katabolic the embryo is male and in common with the rest of the sex the developed organism exhibits katabolic qualities; if the ovum is passing through an anabolic stage the opposite sex is the result.

As explanation of why a period of twelve hours is taken as the length of this metabolic cycle of the germ plasm is now in order. We have already spoken of the general functional periodicity which can be observed in nearly all animal life. As long ago as 1843 Dr. Laycock in an article in the *Lancet*, after citing a number of examples of vital periodicity, comes to these conclusions: He held that there is a general law of periodicity regulating the vital movements in animals; that the approximate periods within which these movements took place could be calculated; and that this unit must be considered one day of twelve hours. He

believed further that the lesser periods were simple and compound multiples of this unit in a numerical ratio analogous to that observed in chemical compounds and that the fundamental unit of the greater period was one week of seven twelve-hour days, equal to one-half of a calendar week. While these assertions are rather dogmatic it would seem that in so far as this period of twelve hours and seven half days are simple divisions of the month they are important. Taking the mean lunar month of twenty-eight days and dividing it, we have as important periods the two weeks or fourteen day period, one week, three and a half days or seven twelve hour periods, and finally the shortest cycle of twelve hours. The longest cycle or one month corresponds to one revolution of the moon, from the perigee to apogee and back to perigee, or a complete cycle of spring and neap tides, while the twelve hour cycle represents one complete ordinary tide cycle corresponding to the upper and lower transit of the moon. Whatever we may assign as the cause, it does seem that many vital phenomena fluctuate in an approximate correspondence with the above designated periods.

For a number of generations it has been noticed that infectious fevers present certain periodic fluctuations. We have been in the habit of noting these periodic changes in many forms of acute disease. In some it seems to be more easily recognized than in others. The ones where it is the most easily observed are those which depend upon a bacterial infection. In very acute diseases we have noted that the termination of a full week generally brings a critical day. A distinct change usually occurs either for better or worse at that time. To a lesser degree this is true of the end of the three and a half day period. Convalescence is often established at the end of the first or second week, or when death takes place it is more likely to occur on the seventh, fourteenth, or twenty-first day, or perhaps the fourth, eleventh, or eighteenth and so on. These changes in the character of the symptom complex are not perhaps so noticeable to the general practitioner, as they would be were all diseases allowed to run their natural course. The day of twenty-four hours is the pathological period most generally observed by physicians. Some disease symptoms do seem to be regularly aggravated or lessened at certain times of the solar day, but we believe this to be due to some daily regulation in the habits of the patient, rather than to any other influence. We believe that a gain would result from the adoption of the twelve hour cycle, as the shortest pathological period.

then three and a half days, seven days, two weeks, and one month.

The incubation of the infectious and contagious diseases seems to vary considerably since the resistance of the patient may be so great as to prolong it over what would be its usual period, but we find that on an average it is limited to these periods; that is, three and a half days, seven days, ten and a half days, and two weeks.

Menstruation probably depends upon the lunar month. Dr. C. A. L. Reed says of this function: "It may be that the function of menstruation will disappear in the course of years, but in its waning recurrences it will still be cyclical in its manifestations. It is a law of life and of all activity.

The respiratory movements are rhythmic and by a deeper breath at every seventh respiration we graft rhythm upon rhythm. There is a recurrence of hunger and thirst and a propensity to sleep, which is not in exact correspondence with the needs of the organism. In healthy persons of both sexes there is a diurnal tide in the pulse rate, the respiration, the arterial tension, and the temperature. More than one observer has come close to a demonstration of that which is inherently probable, a tidal movement in the adult male of the human species, during which all vital processes and the sexual appetite reach a climax and then decline: so that the question has been seriously raised whether it is not true that men menstruate as well as women; and if we take the next step from the physiological to the pathological we find the same inexorable law of rhythm in the periodical recurrence of malarial paroxysms which the discovery of the plasmodium has not fully explained, of epileptic seizures, of maniacal crises, and in the characteristic fever curve of the infectious diseases. Even in the highest intellectual activity we find the same law for the creative power of genius has its ebb and flow."*

Havelock Ellis has called attention to the possibility of the existence of a rudimentary menstrual cycle in man."†

As menstruation corresponds to an increase of activity in the organs of generation in the female, should there be such a cycle in the male, it would probably be represented as suggested above, by an increase of sexual desire. Now this corresponds closely to the facts. There

*A Text Book of Gynecology. C. A. L. Reed.

†Man and Woman, Chap. II. Havelock Ellis. Scribner's Contemporary Science Series.

is in man such a monthly cycle, but upon this is grafted lesser cycles of one week, and three and a half days' duration. Menstruation in woman occurs on an average every twenty-eight days; should there be a delay it is usually three and one-half days or one week in duration. The average duration of the flow is three and one-half days.

This dependence of many phenomena of animal life on the month is very marked. The average time occupied in hatching the eggs of many species of insects is three and one-half days. In some insects the period is one week and a half, as for example, the black caterpillar. Others require from two to six weeks. The larvæ period of the bumble bee is exactly seven days, the moth six weeks, and the common black caterpillar six weeks. The wood piercer bee is in the larvæ state four weeks. The hen lays eggs for three weeks and sets on them three more.* The goose lays for two weeks but sets four. The pigeon sets for two weeks after having laid eggs two weeks. The period of incubation for the ostrich egg is exactly six weeks after four weeks of laying. In the higher mammals there are so many conditions which may retard or hasten birth that the period of gestation is not very accurately determined. Where it is, we generally find it limited by a definite number of months or weeks. Dr. Laycock in one hundred and twenty-nine species of birds and animals found only four exceptions to this rule, while sixty-seven were rigidly exact. This periodicity which we find to be so intimately connected with the month, and running in periods evenly divisible by the twelve hour period, which we know constitutes one complete tide cycle, was noted by Charles Darwin. A hint is let fall in *The Descent of Man* that is pregnant with suggestion. He says: "All vital functions tend to run their course in fixed and recurrent periods and in tidal animals the periods would probably be lunar, for such animals must have been left dry or covered deep with water, supplied with copious food or stinted during endless generations at regular lunar intervals. If then the vertebrata are descended from an animal allied to the existing tidal ascidians the mysterious fact that with the higher and

*Albini found that hens after separation from the cock for the first week laid nothing but fertile eggs, but on the ninth and tenth days both fertile and infertile eggs were laid. On the twelfth day all the eggs were infertile, but fertile eggs would again show and were laid even as late as the eighteenth day. From which we gather that the days having the highest average of fertility were approximately the seventh and fourteenth.

now terrestrial verterbrata many normal and abnormal vital processes run their course according to lunar periods, is rendered intelligible. A recurrent period, if approximately of the right duration when once gained would not, as far as we can judge, be liable to be changed, consequently it might thus be transmitted to almost any number of generations. This conclusion, if it could be proved sound, would be curious, for we could then see that the period of gestation in each mammal and the hatching of birds' eggs and many other vital processes still betrayed the primordial birthplace of these animals."*

If we assume with Darwin that the vertebrata are descended from some tidal animal, which, as he says, must have been subjected for many millions of generations to such marked alterations in its environment as a complete immersion in sea water followed by a complete exposure to the air and sunlight in periods six hours in length, synchronizing perfectly with the incoming and outgoing tide, we must admit the possibility of the rhythm then established, being maintained by heredity through as many more generations of cells even though they may not be subject to the same conditions as the ancestral cell. That it is still maintained in the germ plasm should seem all the more plausible when it is remembered that many functions and vital phenomena of the fully developed organism still display this tendency, as has been shown, to run their courses in more or less definite lunar intervals. It is generally believed by evolutionists that the beginnings of life on this earth were first manifested in sea water: but there must have been a period when in the migration of life from sea to land these animals inhabited for countless millions of generations the tide ways and shore, for it is inconceivable that any species could survive the sudden change from water to land. Now what effect would this alternate immersion and drying in these tideways have? Would it not produce on these primitive cells alternate active and passive, or anabolic and katabolic effects, states which we see perpetuated in the two sexes even to this day? Flood tide would be a period of activity, of seeking for food, of excretion, of ingestion, of avoiding enemies, of darting here and there, or in earlier times, perhaps as we see the simple cell to-day, floating in the water and rejecting or seizing and assimilating different bits of food which may happen to drift in its direction. On the other, the ebb tide marked a period of passiveness or anabolism, gorged with food

*Descent of Man,

which is now building up the organism, immobile and passive, the primitive cell rests upon the surface of the sands or vast marshy tracts of land, very much as Prof. Thompson describes the female cochineal insect as resting passive, sluggish and immovable upon the cactus plant.

Could any conditions be imagined which would create in the cell periodic cycles, typifying more vividly the states which biologists have found to constitute the essential distinction between the sexes?

PART V.

IT has long been noted by embryologists that the developing organism in the womb of its mother passes through many different stages resembling in turn the varied form of animal life constituting the line of ancestry of its species.* The ovum before fertilization resembles the simple organism from which in all probability the vertebrata sprung. We also know that characteristics or variations last acquired are the most easily lost, while those earliest acquired are the most fixed. Functional rythms are lost much as are physical variations. It is not then unreasonable to suppose that while these functional rhythms, fluctuating according to lunar intervals, may be to a degree lost or distorted in the developed organism, in the protected sphere of the germ plasm they retain all the regularity which characterized the anabolic and katabolic change in the ancestral cells which inhabited for so many millions of generations the seashores and tideways of the earth.

Our attention was first called to this subject some thirty years ago by a well-known physician of Philadelphia, who, in the course of a lecture, made the remark that there was a widespread belief among many communities inhabiting the seacoast that children are more likely to be born when the tide is coming in, and the sick die at its ebbing.

He held that there was some basis in fact for this belief. Although under the impression that it was probably based only upon the analogy so evident between the ebbing tide and the ebbing life, the incoming tide and the incoming life, rather than upon any series

* While we cannot subscribe to the philosophy of evolution as a whole, it is interesting to note how near Darwin came to expressing the hypothesis that these tidal conditions originated the sex distinction, or at least to speculate upon what he might have had to say if the idea had been pursued further.

of observations, we nevertheless determined, as opportunity presented itself, to subject it to test. Our geographical position being inland, lat. 39 north, long. 84.5 west, we took the Philadelphia tide tables as being approximately in the same latitude, and knowing that time and tide advance together, the above tide table answered all practical purposes for making observations from day to day.

It is, of course, true that many points on the same meridian experience high and low tide at different times. The configuration of the ocean bed, the position of a place with reference to the mouth of a river, bays, sounds, gulfs, inlets, etc., make a considerable difference in the time of high and low tide at that place in comparison with some other place perhaps only a few hundred miles to the north or south of it. The tidal establishment of every point must then be calculated separately. Now, authorities are not quite agreed upon just where, with the reference to the earth and the moon, high tide would be found, were the seas of the same depth throughout and the tidal wave unchecked by continents. It is probable, however, that any particular point would under these circumstances experience a high tide at exactly the upper and lower transit of the moon. However, the fact that the real high and low tides do not correspond, owing to the conditions already mentioned, with the theoretic tide, makes no particular difference as far as this inquiry is concerned. The point of importance is the *selection of a twelve-hour cycle changing every day in accordance with the tidal or lunar change.*

We designated the incoming tidal curve, for our latitude and longitude, the positive or active period, and the outgoing tidal curve as the negative or passive period. On this basis we found that deaths of persons well advanced in years where the end was a gradual one, and uninterfered with by stimulation, showed a considerable percentage in favor of the passive or negative hours. On the other hand, births were more frequent during the period opposite to this one—that is, the active or positive half of the tidal change. There are, of course, a multiplicity of accidents which may delay or promote a birth, but those parturitions in which the course of nature was the least interfered with are the ones here referred to. *Any others, whether they favored the hypothesis or not, were not considered.* The preponderance of births during the active hours is more striking than is the preponderance of deaths during the passive hours. We know of no other condition

in which this alternate change of functional activity can better be observed than during the progress of a protracted labor. There are six hours of active uterine contractions followed by six hours of comparative rest. During the former period the expelling or longitudinal fibres are the more active, while during the latter the circular fibres are occasionally brought into play to mold the head or presenting part. The contractions of this period are much less regular and more trying to the parturient, and there is apparently but little progress.

Should instrumental interference prove necessary, a knowledge of these changes is beneficial in pointing out the active hours, the time when we believe this interference will yield the best results. Since observing these periodic changes in parturitions a remarkable freedom from perineal lacerations or accidents of any sort has been noted. Were it not without the province of this paper a number of cases might be cited in which this periodic change is strikingly exemplified.

It has been intimated that a lunar cycle which, in the developed organism is rudimentary, lost, or obscured by other influences might, in the original germ plasm, be supposed to retain all of its original distinctness and activity. This is what, in our opinion, has proved to be the case. When it occurred to us that sex might depend upon this periodicity in the organism, just as births and deaths were shown to be affected by it, there went with the thought some considerable doubt, for this periodic change seemed to effect the vital activity of the adult organism, while sex we had always supposed to depend upon some structural characteristic of the egg. However, it was found that in determining the sex the tide cycle was more to be depended upon than it is in the case of deaths or births. Where the time of sexual intercourse was definitely known no failure to predict the sex of the offspring has yet been noted. Coitus taking place during the positive cycle or katabolic change in the germ cell a male is the result, while if during the negative or passive cycle a female is conceived. All those cases in which the time of intercourse was near the turn of the cycle were ruled out, whether they favored the hypothesis or not. Twins of different sexes are the result of two conceptions more than six hours apart, or they may be of the same sex, but both conceived during a negative or positive period, the periods being the same in character, but from twelve hours to two weeks or more apart. Should they be of different sexes, but the result of a single coitus, we believe it will be found that this occurred very close to the turn

of the cycle, showing that one ovum was in all probability fertilized during one period and the other during the succeeding period. In one instance a cow, served but once, gave birth to twin calves, male and female. On investigation it was found that the cow was bred at the turn of the cycle. This is the only circumstance of this kind known to us.

Every physican has observed in his obstetrical practice, without being able to account for it, that for periods of several days one or the other sex will show a marked preponderance. This has been noted by us throughout many years of practice. As an instance, from the 23d to the 28th of November, 1892, five births were attended, all of which were females. Counting back to the period of impregnation, it was found that the hours covering the retiring time of the masses were negative. Now, taking groups of boys and tracing back in the same way, it will be found that these hours are positive. By examining city birth records the sexes will often be found grouped in this way. It is hardly probable that this is coincidence.

A number of cases where our patients have been successful in securing the sex desired might be mentioned, while as many more instances of a like success following the breeding of horses and cattle have been observed.

A few of the former class of cases will now be cited. Mrs. A. had given birth to five girls, and much desired a boy. Sexual relations were permitted at no other time except near the middle of a positive period until pregnancy occurred, with a boy as the result. No attention was paid to diet or the time of the menstrual month.

A couple recently married desired a boy. Sexual union during one month was practiced only in positive hours. Conception took place during this month with the desired result. A year later a girl was procured by observing this rule in negative hours.

Mrs. W., of a Southern State, wrote asking information, as she wished a girl. A list of negative periods was sent her. In due time she reported the desired daughter.

Mr. X., a shrewd but uneducated farmer, had been blessed with a family of boys. He very much desired a girl, and sought consultation with this in view. A list of negative periods was furnished him, with instructions to follow it closely. Nothing was heard from him for about one year, when he happened in the office one afternoon to remind us that our services might be required within the next few days. When asked if he

had followed the instructions given him, he replied that he had "got all mixed up on those figures"; he had, however, carefully noted the exact hour and day impregnation occurred. On looking this up, the time was found to have been in the middle of a positive period. He was informed that under the circumstances he must look for another boy, and much to his regret the prediction was verified.

Mrs. C. had given birth to three girls. The proper instructions were given and the cycles were watched with the result that the fourth child was the wished-for boy.

Mr. W. desired a boy. He was furnished a table with instructions. Coition was indulged in for months only in positive hours. The result was twins, both boys, born one-half hour apart, but enclosed in different membranes and nourished through separate placentas. Before the second one was born it was explained to the father that, although another child was expected—a second unbroken membrane appearing—they would not be true twins, and that they would not resemble each other very closely. At birth the first was larger and better developed than the second, and perhaps ten days or two weeks the elder in utero. They are now over a year old and no more alike than brothers of separate births, the smaller at birth being now much larger than the other. A score or more of similar cases could be cited.

We find that the positive hours for the locality mentioned are simultaneous with the rising tide at Philadelphia, negative and positive time cycles alternating. When male offspring are desired, intercourse should be permitted only near the middle of the positive hours; when females are desired observe the same rule, but in negative hours.

We will now briefly summarize our conclusions: In the first section of this paper it was shown that all theories of the determination of sex have proved inadequate, there always remaining residual phenomena which they fail to explain. The sexes were shown to be approximately equal both physiologically and in numbers. Sex is held to be a property of the embryo back to the time of fertilization. Reasons were given for believing that the ovum is not male or female, depending upon the one selected. The analogies between the sexual organs of the male and female sex, the presence of rudimentary secondary sexual characters, the acquirement of characters of the opposite sex under some circumstances, the wide distribution of the tertiary char-

acters of one sex among the members of the opposite sex, and the inheritance of secondary sexual characters through a parent of the opposite sex, all lead us to conclude that the ovum previous to fertilization is hermaphroditic. The distinction between true or homologous twins and double births was dwelt upon. All the facts lead to the conclusion that the sex depends upon the time of the fertilization of the ovum. The time of the day, week, month, menstrual or lunar, and year is ruled out. The time with reference to any physical or psychological variations in the parents is also ruled out. There remains only the time with reference to the tide cycle or some periodic fluctuation of the germ plasm itself.

In the second section of this paper the opinion was expressed that if the ovum is hermaphroditic, it is improbable that it retains continually the delicate balance between the sexes necessary for the expression of an absolute hermaphroditism. The structure of both sexes being present, it follows that in all probability the ovum functions first in one direction and then in the other. This rhythm is in all probability analogous to the anabolism and katabolism which has been shown to constitute the essential difference between the sexes. The possibility of this rhythm in the germ cell at first depending upon and now synchronizing with the tide cycle is suggested. The conclusion is reached that sex is determined by the time of fertilization, with reference to an anabolic and katabolic rhythm within the ovum. Fertilization of the ovum probably takes place at or near the time of union of the sexes. This rhythm extends over a period of twelve hours, six being active or masculine, and six passive or feminine, and changes from day to day as do the tides.

It is evident from the nature of the case that, at least as far as man is concerned, clinical evidence tending to further substantiate that already given must necessarily be obtained slowly and with considerable difficulty. However, we have given this question attention for a number of years, and while even in that time the instances where it has been possible to learn the exact hour, day, and year of a sexual union resulting in offspring cannot be considered large; yet, we repeat, in every instance where this has been definitely determined, the sex has been successfully predicted. Therefore, in closing this paper, we feel justified in asking any who may be interested to investigate this subject.

Middletown, Ohio, June, 1906.